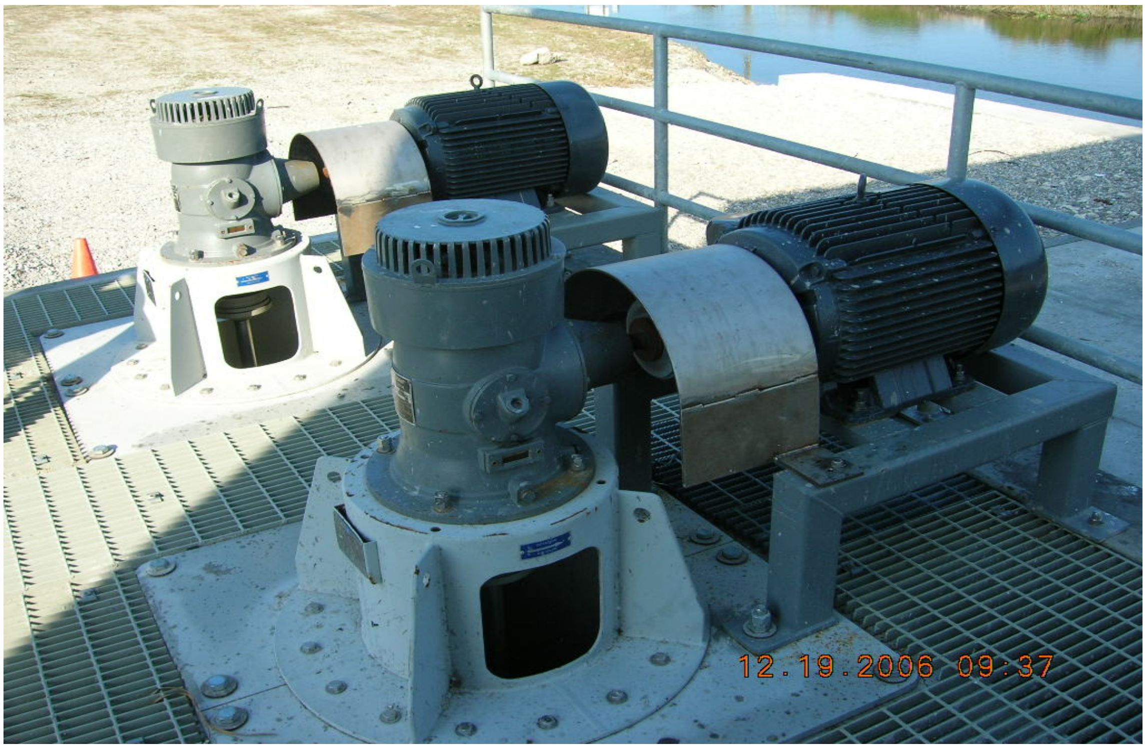
Flow Rating Analysis for Pump Station G349C

Stormwater Treatment Area No 5

Technical Publication OHDM - ERA # 454



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Executive Summary

A rating analysis of G349C was carried out using the conventional case 8 model. The equation developed yields discharge rates that are within 0.21 percent of the discharges derived from the pump station rating curve under the expected range of static heads. Given the uncertainties inherent to the hydraulic head loss calculations, it is recommended that the rating equations be recalibrated with measured flows of acceptable quality.

Acknowledgements

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Introduction

Pump station G349C is an inflow station for Storm Water Treatment area No. 5. It is located at the Northwest Corner of STA cell 1B. There are two identical electric pumps at this station. Both pumps are axial flow, vertical segmented line shaft pumps manufactured by the Morrison Pump Company. The pump performance curve is shown in Figure 1. The operating conditions associated with the specified performance of the pumps are as follows:

Elevation of Pump Station:	+18 ft NGVD
Fluid Type:	Fresh Water
Specific Gravity:	1.0 s.g.
Fluid Temperature:	80 Deg. F
Design Capacity:	10,000 GPM
Design Total Dynamic Head:	16.1 ft TDH
Design Pump Bowl Efficiency:	83 %
Design Pump Speed:	1015 RPM
Max. Absorbed Power:	53 HP (including transmission losses)
Motor Driver Horsepower:	60 HP (per specification)

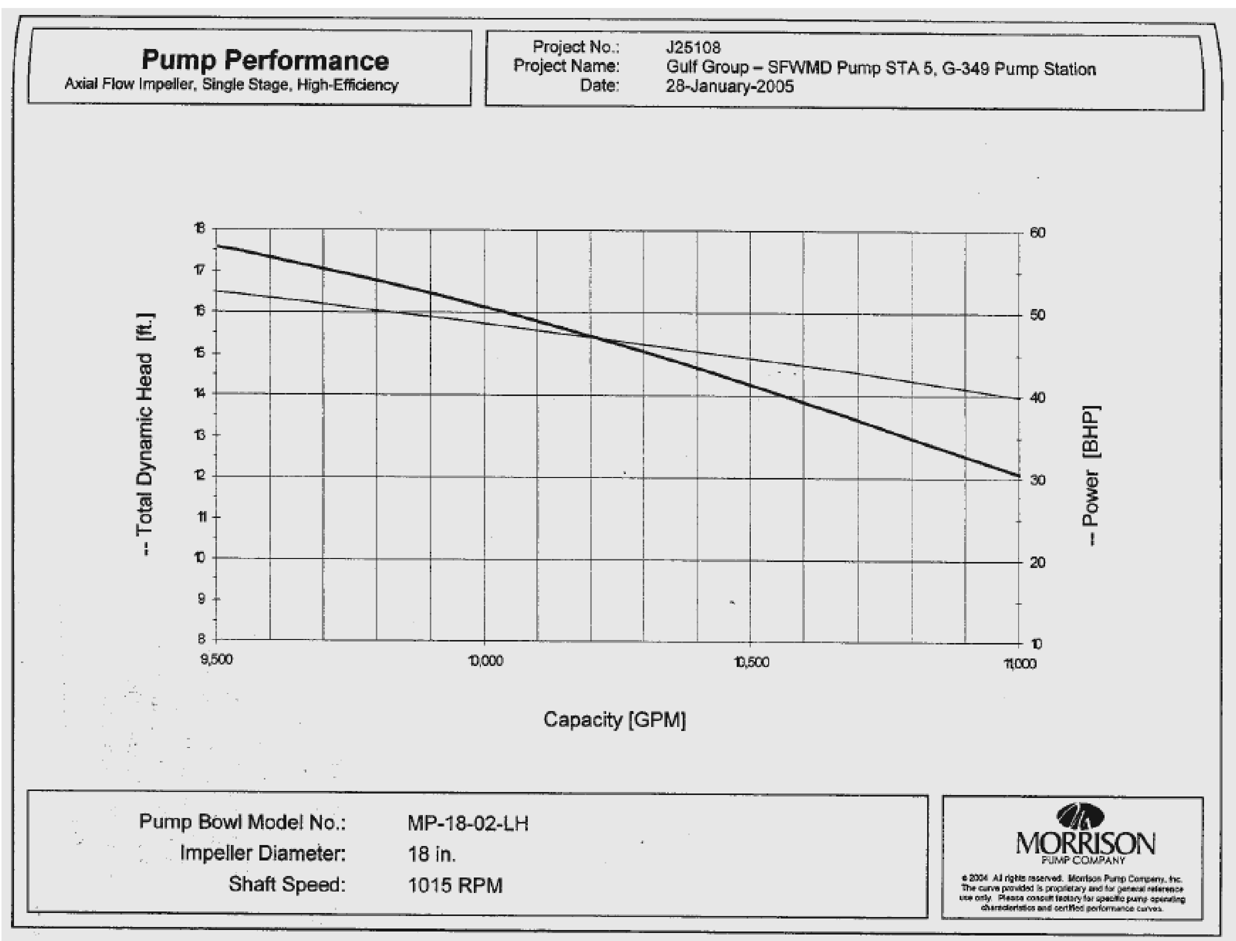

Figure 1. G349C pump performance curve.

Objectives and Scope

The primary purpose of the rating analyses conducted in this study is to enable flows through G349C to be estimated using measured head water elevations, tail water elevations and pump motor speeds. The hydraulic rating equations are based on pump performance characteristics, hydraulic properties of piping configurations and appurtenances, and engineering principles. Since G349C became operational only recently, the rating equations could not be calibrated to stream flow measurements since none were available at the time this rating analysis was conducted.

Station Design

Cross sectional and plan views of the pump station design are shown in figure 2. Table 1 contains the dimensions of the station piping. Table 2 contains estimates of pipe roughness for steel pipes.

Table 1. Dimensions of station piping at G349C.

Property	*Dimension*	*Source*
OD	20 in	*plans*
Wall Thickness	0.375 in	Sanks(1989); proj specs
Length	35.8 ft	*plans*
Area	2.02 ft^2	

Table 2. Estimates of steel pipe roughness.

Pipe Head Losses				
ε =	0.00015	ft	new steel	*Hydraulic Inst.*
ε =	0.00133	ft	old steel	*Sanks (1989)*

Rating Analysis

The model rating equation applied to G349C is the standard case 8 model (Imru and Wang, 2004):

$$Q = A\left(\frac{N}{N_O}\right) + BH^C\left(\frac{N_O}{N}\right)^{2C-1} \qquad \text{...} (1)$$

where Q is the discharge at N RPM, H is the TSH, N_O is the design engine or pump speed, and A, B and C are coefficients to be determined through regression. The form of this expression was determined through dimensional analysis and is based on the pump affinity laws. For pumps driven by electric motors, N_O = N so the ratios involving these parameters are eliminated and the equation becomes:

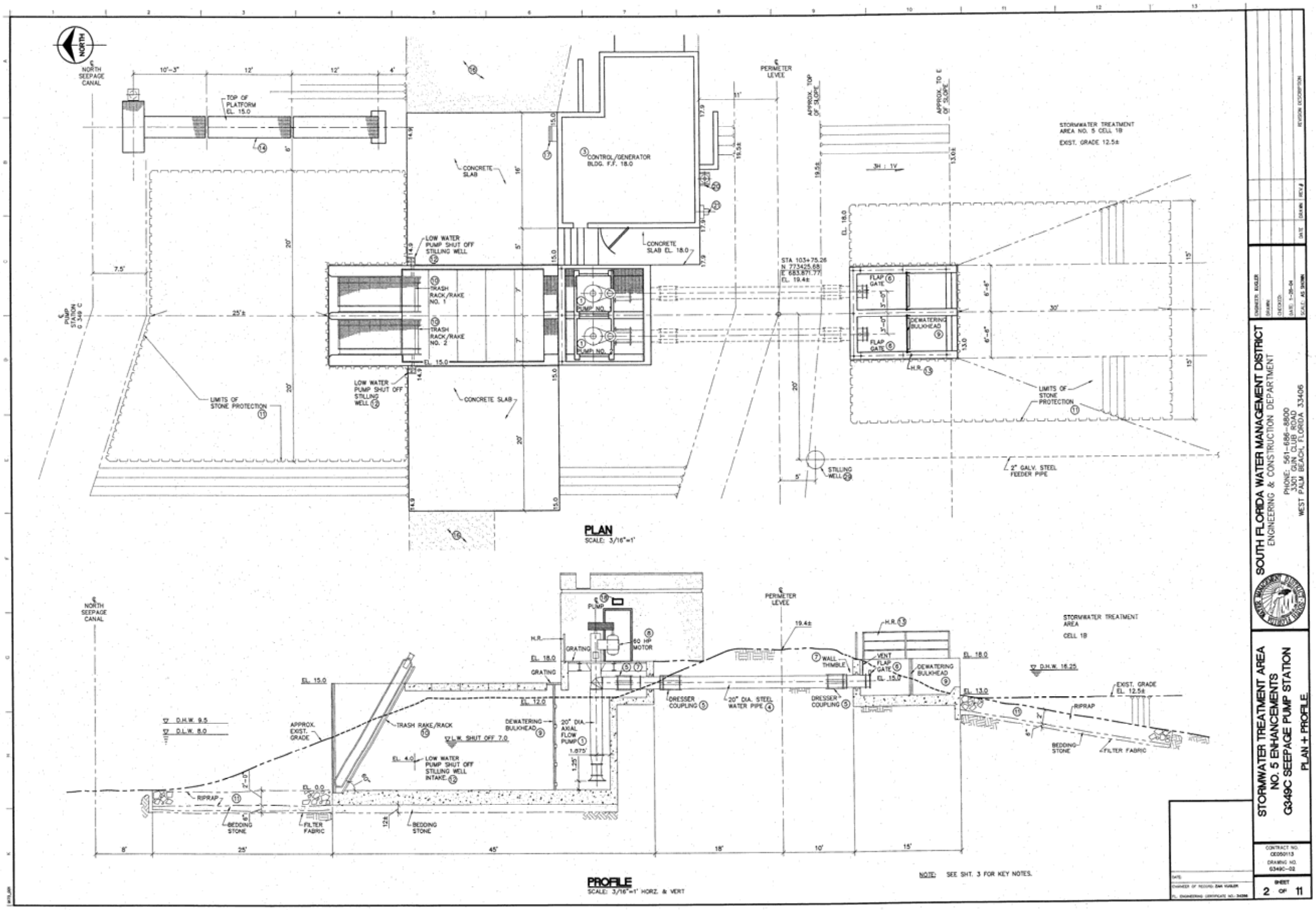

Figure 2. Plan and section views of pump station G349C

$$Q = A + BH^{C} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Figure 3 depicts the TSH vs. flow relationship for G-349C determined from the pump performance curve and computed head losses. For comparative purposes, the pump performance curve is also shown. The associated head loss computations are provided in appendix A. Equation (1) was fit to the TSH vs. Q curve based on average head losses. The resulting values of A, B and C are provided in table 3. Table 4 provides a comparison of the rating equation with the pump station performance curve.

Table 3. Regression parameters for the G349C rating.

Regression Parameter for Equation (1)	A	B	C
Approximate lower 95% C.I.	25.7174	-0.0237	1.9139
Estimated Value	26.0296	-0.0141	2.1399
Approximate upper 95% C.I.	26.3418	-0.0046	2.3658

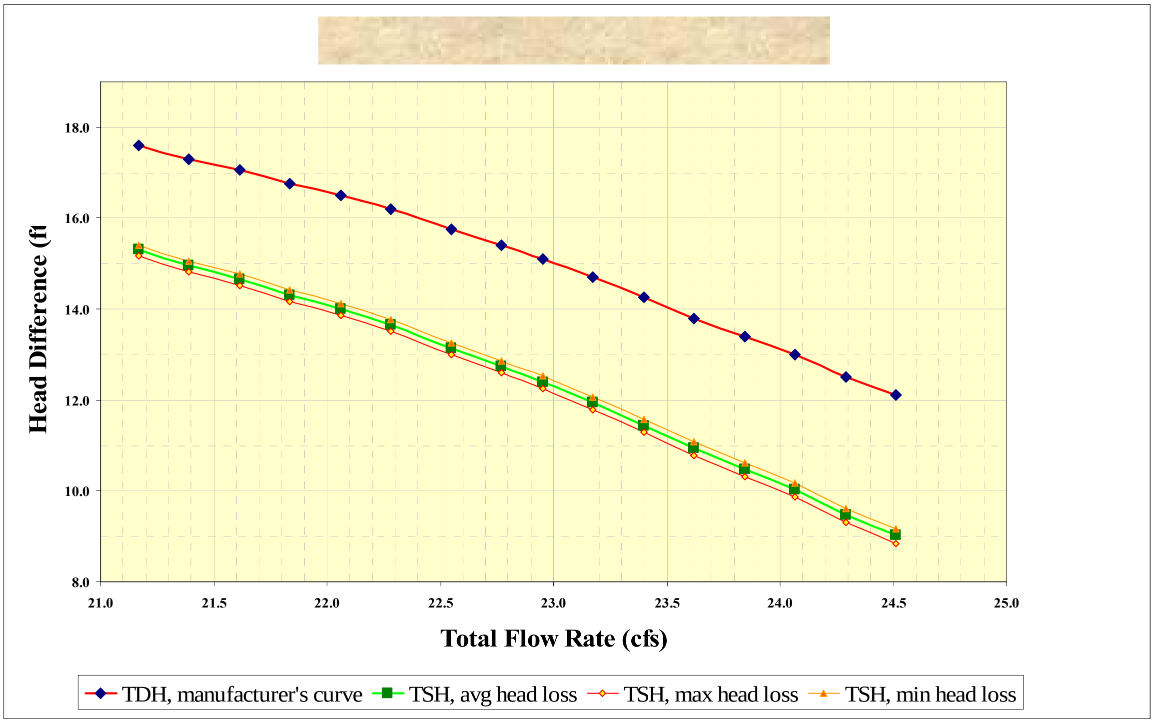

Figure 3. Modified pump curve for G349C.

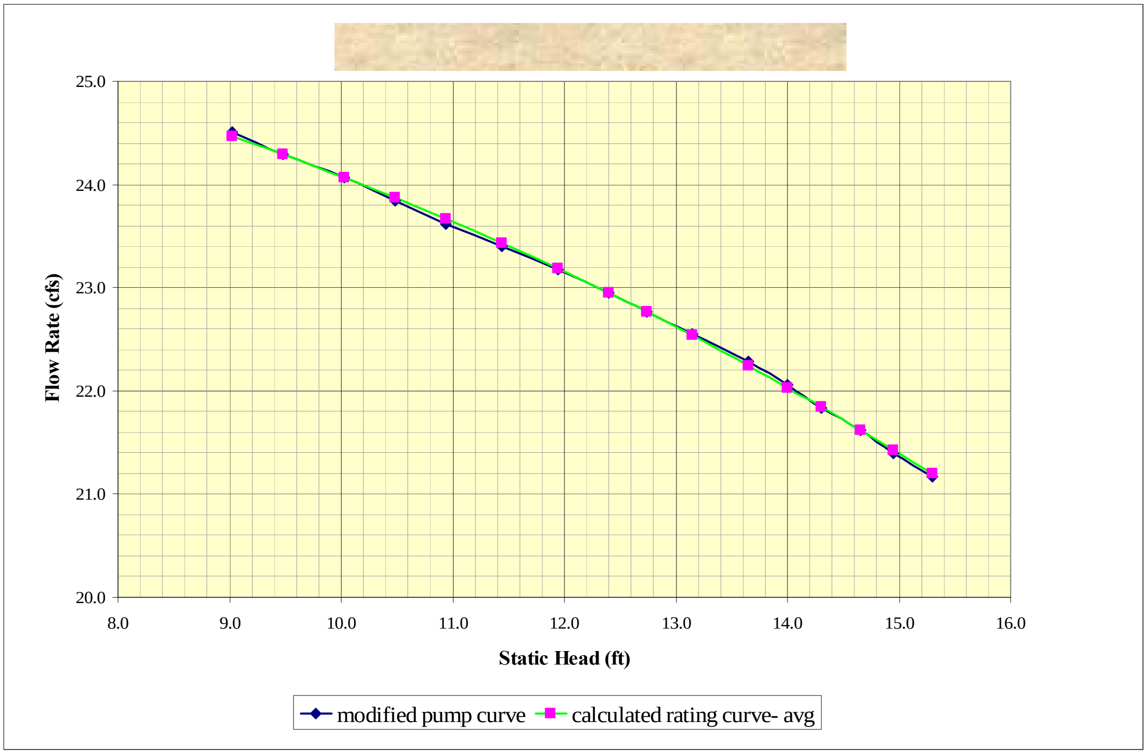

Figure 4. Flow rating curve for G349C.

Table 4. A comparison between the rating equation and pump station curve.

TSH (ft)	$Q_{ps\ curve}$ (cfs)	Q_{rating} (cfs)	Error (%)
15.30	21.17	21.19	0.12
14.95	21.39	21.43	0.17
14.65	21.61	21.62	0.03
14.30	21.84	21.84	0.03
14.00	22.06	22.03	-0.14
13.65	22.28	22.24	-0.19
13.14	22.55	22.54	-0.05
12.74	22.77	22.76	-0.04
12.40	22.95	22.95	-0.02
11.95	23.17	23.18	0.03
11.44	23.40	23.43	0.15
10.94	23.62	23.67	0.21
10.49	23.84	23.88	0.14
10.03	24.07	24.07	0.02
9.48	24.29	24.30	0.03
9.02	24.51	24.47	-0.18

Stream-Gauging Needs

The stream-gauging data needs for pump station G349C are summarized in Table 6. Indicated is the targeted number of flow measurements under each of the operating conditions.

Table 2. Stream-gauging needs for G349C.

Pump	TSH (ft)	Number of Measurements needed (@RPM =1760)
Unit 1 or 2	3~6	*5*
	6~9	*5*
	9~12	*5*

Summary and Conclusions

A rating analysis of G349C pump station was carried out using the conventional case 8 model. A rating equation was developed for two identical pump units configured the same way. The equation yields discharge rates that are within 0.21% of the discharges derived from the pump station rating curve under the expected range of static heads. Given the uncertainties inherent to the modified pump station curves discussed above, it is recommended that the rating equation be calibrated with measured flows of acceptable quality.

References

Hydraulic Institute (1990). Hydraulic Institute Engineering Data Book. Second Edition.

Imru, M. and Y. Wang. 2004. Flow Rating Development for New Pump Stations. Technical Publication EMA # 419, South Florida Water Management District, West Palm Beach, Florida, 44 pp.

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Appendix A. Head Loss Calculations

Minimum head loss calcuations

1760 RPM			Swamee & Jain(1976)							
TDH(ft)	Q (GPM)	Q(cfs)	V(ft/s)	N_R	$V^2/2g$ (ft)	f	$h_l = f(L/D)V^2/2g$	$h_m = \Sigma KV^2/2g$	Total Head Loss (ft)	Static Head (ft)
17.60	9500	21.17	10.47	1680213	1.70	0.01290	0.49	1.70	2.19	15.41
17.30	9600	21.39	10.58	1697900	1.74	0.01289	0.50	1.74	2.24	15.06
17.05	9700	21.61	10.69	1715586	1.78	0.01288	0.51	1.78	2.29	14.76
16.75	9800	21.84	10.80	1733273	1.81	0.01287	0.52	1.81	2.33	14.42
16.50	9900	22.06	10.92	1750959	1.85	0.01287	0.53	1.85	2.38	14.12
16.20	10000	22.28	11.03	1768645	1.89	0.01286	0.54	1.89	2.43	13.77
15.75	10120	22.55	11.16	1789811	1.93	0.01285	0.55	1.93	2.49	13.26
15.40	10218	22.77	11.27	1807273	1.97	0.01284	0.56	1.97	2.54	12.86
15.10	10300	22.95	11.36	1821705	2.00	0.01283	0.57	2.00	2.58	12.52
14.70	10400	23.17	11.47	1839391	2.04	0.01283	0.58	2.04	2.63	12.07
14.25	10500	23.40	11.58	1857078	2.08	0.01282	0.60	2.08	2.68	11.57
13.80	10600	23.62	11.69	1874764	2.12	0.01281	0.61	2.12	2.73	11.07
13.40	10700	23.84	11.80	1892451	2.16	0.01280	0.62	2.16	2.78	10.62
13.00	10800	24.07	11.91	1910137	2.20	0.01280	0.63	2.20	2.83	10.17
12.50	10900	24.29	12.02	1927824	2.24	0.01279	0.64	2.24	2.88	9.62
12.10	11000	24.51	12.13	1945510	2.28	0.01278	0.65	2.28	2.94	9.16

Average head loss calcuations

1760 RPM			$f_{av} = sqrt(f_{min} f_{max})$						
TDH(ft)	**Q (GPM)**	**Q(cfs)**	**V(ft/s)**	**$V^2/2g$ (ft)**	**f**	**$h_l = f(L/D)V^2/2g$**	**$h_m = \Sigma KV^2/2g$**	**Total Head Loss (ft)**	**Static Head (ft)**
17.60	9500	21.17	10.47	1.70	0.01568	0.60	1.70	2.30	15.30
17.30	9600	21.39	10.58	1.74	0.01567	0.61	1.74	2.35	14.95
17.05	9700	21.61	10.69	1.78	0.01566	0.62	1.78	2.40	14.65
16.75	9800	21.84	10.80	1.81	0.01566	0.63	1.81	2.45	14.30
16.50	9900	22.06	10.92	1.85	0.01565	0.65	1.85	2.50	14.00
16.20	10000	22.28	11.03	1.89	0.01565	0.66	1.89	2.55	13.65
15.75	10120	22.55	11.16	1.93	0.01564	0.67	1.93	2.61	13.14
15.40	10218	22.77	11.27	1.97	0.01563	0.69	1.97	2.66	12.74
15.10	10300	22.95	11.36	2.00	0.01563	0.70	2.00	2.70	12.40
14.70	10400	23.17	11.47	2.04	0.01562	0.71	2.04	2.75	11.95
14.25	10500	23.40	11.58	2.08	0.01562	0.73	2.08	2.81	11.44
13.80	10600	23.62	11.69	2.12	0.01561	0.74	2.12	2.86	10.94
13.40	10700	23.84	11.80	2.16	0.01561	0.75	2.16	2.91	10.49
13.00	10800	24.07	11.91	2.20	0.01560	0.77	2.20	2.97	10.03
12.50	10900	24.29	12.02	2.24	0.01560	0.78	2.24	3.02	9.48
12.10	11000	24.51	12.13	2.28	0.01559	0.79	2.28	3.08	9.02

Maximum head loss calculations

1760 RPM			Swamee & Jain(1976)							
TDH(ft)	Q (GPM)	Q(cfs)	V(ft/s)	N_R	$V^2/2g$ (ft)	f	$h_l = f(L/D)V^2/2g$	$h_m = \Sigma KV^2/2g$	Total Head Loss (ft)	Static Head (ft)
17.60	9500	21.17	10.47	1680213	1.70	0.01905	0.72	1.70	2.43	15.17
17.30	9600	21.39	10.58	1697900	1.74	0.01905	0.74	1.74	2.48	14.82
17.05	9700	21.61	10.69	1715586	1.78	0.01904	0.75	1.78	2.53	14.52
16.75	9800	21.84	10.80	1733273	1.81	0.01904	0.77	1.81	2.58	14.17
16.50	9900	22.06	10.92	1750959	1.85	0.01904	0.79	1.85	2.64	13.86
16.20	10000	22.28	11.03	1768645	1.89	0.01904	0.80	1.89	2.69	13.51
15.75	10120	22.55	11.16	1789811	1.93	0.01903	0.82	1.93	2.75	13.00
15.40	10218	22.77	11.27	1807273	1.97	0.01903	0.84	1.97	2.81	12.59
15.10	10300	22.95	11.36	1821705	2.00	0.01903	0.85	2.00	2.85	12.25
14.70	10400	23.17	11.47	1839391	2.04	0.01903	0.87	2.04	2.91	11.79
14.25	10500	23.40	11.58	1857078	2.08	0.01903	0.88	2.08	2.96	11.29
13.80	10600	23.62	11.69	1874764	2.12	0.01902	0.90	2.12	3.02	10.78
13.40	10700	23.84	11.80	1892451	2.16	0.01902	0.92	2.16	3.08	10.32
13.00	10800	24.07	11.91	1910137	2.20	0.01902	0.93	2.20	3.14	9.86
12.50	10900	24.29	12.02	1927824	2.24	0.01902	0.95	2.24	3.19	9.31
12.10	11000	24.51	12.13	1945510	2.28	0.01902	0.97	2.28	3.25	8.85